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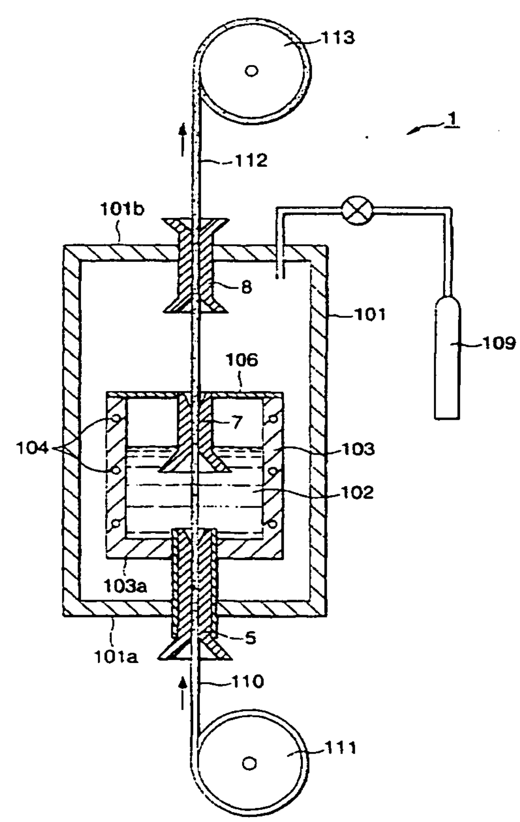
(54) Apparatus for continuous pressure infiltration of metal fiberbundles

(57) An apparatus for coating a fiber-reinforced metal matrix composite wire includes an entering orifice provided at an inlet for inserting inorganic fiber bundles, an exit orifice provided at an outlet for inserting the inorganic fiber bundles, and a bath container holding therein molten metal, an enlarged-diameter section is formed at least at the end of each of the orifices from which the inorganic fibers are introduced, wherein the molten metal infiltrates to the inside of the inorganic fiber bundles when the inorganic fiber bundles are inserted into the bath container.

FIG. 1



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Description

BACKGROUND OF INVENTION

Field of the Invention

[0001] The present invention relates to an apparatus for continuos pressure infiltration of metal into fiber bundles to manufacture fiber-reinforced metal matrix composite wires, wherein inorganic fiber bundles comprising strands of carbon-based fibers are passed through a molten metal such as aluminum, which infiltrates into reinforce the fiber bundles.

Related art

[0002] To this end, the inorganic fiber bundles must retain a large amount of metal by means of metal infiltration into the gaps among the fiber. US Patent No. 5,736,199 describes such a method of manufacturing a fiber-reinforced metal matrix composite wire.

[0003] The manufacturing method employs a metal infiltration apparatus 100 shown in FIG. 4. Referring to the figure, a molten metal container (bath container) 103 for melting and holding a metal 102, such as aluminum, aluminum alloy, or copper, is housed in a pressure chamber 101. The bath container 103 is heated by means of a heater 104.

[0004] Inorganic fiber bundles continuously pass through the bath container 103 which is equipped with an entering orifice 105 and an intermediate orifice 107. The entering orifice 105 is connected to a bottom surface 101a of the pressure chamber 101 and allows inorganic fiber bundles to enter the bath container 103. The intermediate orifice 107 extends from a position within the molten metal 102 to a closure member 106 which covers the opening section of the bath container 103. Furthermore, an exit orifice 108 is provided in an upper surface 101b of the pressure chamber 101 to allow the metal infiltrated inorganic fiber bundles to exit from the pressure chamber 101. The intermediate orifice 107 peels off the excess molten metal and prevents the surface impurities of the molten metal from adhering on the fiber.

[0005] Function of the orifices 105, 107, and 108 will be described by taking the entering orifice 105 as an example. As shown in FIG. 5, the orifice 105 is cylindrical in shape, and the exterior surface of the orifice 105 is covered with a cooling cover 114. An insertion hole 105b is formed along the center axis of an orifice body 105a ,and has an internal diameter slightly greater than the outer diameter of fiber bundles 110 which travels upward into the insertion hole 105b. The temperature difference is within 150°C~200°C between the upper end and the lower end of the orifice 105.

[0006] A non-reacting gas, such as argon gas or nitrogen gas, is introduced into the pressure chamber 101 from a gas supply source 109; thus,the interior space of both the pressure chamber 101 and the bath container 103 are respectively maintained at preset pressures when the fiber bundles are infiltrated by metal.

[0007] In the infiltration apparatus 100 having such a configuration, inorganic fiber bundles 110 that are fed continuously from a bobbin 111, are introduced into the bath container 103 by way of the entering orifice 105 and are brought into contact with the molten metal 102. Since the interior spaces of both the pressure chamber 101 and the bath container 103 are pressurized by a gas supplied from the gas supply source 109, the molten metal 102 infiltrates into the interfiber spacing in the inorganic fiber bundles 110. The metal infiltrated fiber bundles 110 then leave the bath container 103 by way of the intermediate orifice 107.

[0008] While the inorganic fiber bundles travel through the inside of the pressure chamber 101, the molten metal 102 that has adhered to and infiltrated into the inorganic fiber bundles 110 is cooled, so that a part of the metal solidifies around the inorganic fiber bundles 110.

[0009] Subsequently, a take-up bobbin 113 takes up a fiber-reinforced metal matrix composite wire 112 coming out of the pressure chamber 101 through the exit orifice 108.

[0010] When the diameter of a fiber-reinforce metal matrix composite wire is reduced the through holes of the orifices must become smaller accordingly, making it difficult to pass fiber bundles through holes in the foregoing method of manufacturing fiber-reinforced metal matrix composite wires.

[0011] Also the walls of the through holes have been made of carbon-based materials, such as graphite, which do not exhibit good durability against wear caused by friction between the walls and the moving wire. If, on the other hand, the walls are made of materials with high resistance against abrasion the fiber bundles become more vuluerable to breakage within the orifice.

[0012] The objective of the present invention, conceived to solve such a problem, is to provide an apparatus for the continuous pressure infiltration process with means, , which facilitates insertion of fiber bundles into orifices, realizes superior workability, and ensures consistent wire quality by preventing breakage in the fiber bundles during a manufacturing process.

SUMMARY OF INVENTION

[0013] The foregoing problems can be solved by an apparatus for coating a fiber-reinforced composite line according to the present invention. The apparatus includes an entering orifice, an exit orifice and a bath container (a molten metal container), wherein the molten metal infiltrates into the inorganic fiber bundles moving through the bath container. The apparatus is provided by

(1) an enlarged-diameter section is formed at least

one of the entering ends and the exit ends.

(2) the orifices preferably formed from at least one material which has low reactivity with both the molten metal and the inorganic fiber bundles, and selected from stainl ss steel, tantalum, molybdenum, platinum, tungsten, and sintered zirconia-ceramic-based materials.

(3) the interior surface of the passageways in the orifices are preferably finished with a mirror finish.

[0014] In the apparatus of the present invention, the enlarged-diameter section formed at least at the end of the orifice allows for the end of the fiber bundles to be inserted readily into the respective orifices. Furthermore, the mirror-finished interior surface of the insertion hole allows smooth insertion of fiber bundles through the orifices.

[0015] The material of the orifices has low reactivity with molten metal and inorganic fiber bundles; hence, breakage of the fiber bundles within the orifices can be prevented unfailingly while the durability of the orifices is ensured.

[0016] Since the fiber bundles can be readily inserted into the orifices, and breakage of the fiber bundles during the manufacturing step can be prevented, a fiber-reinforced composite wire with consistent quality can be manufactured efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a cross-sectional view showing an apparatus for continuous pressure infiltration of metal into fiber bundles as one embodiment of the present invention; FIG. 2 is a cross-sectional view showing one embodiment of an orifice shown in FIG. 1;

FIG. 3 is a cross-sectional view showing another embodiment of the orifice shown in FIG. 1;

FIG. 4 is a cross-sectional view showing a conventional apparatus for coating a fiber-reinforced composite line; and

FIG. 5 is a perspective view showing an orifice shown in FIG. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] A fiber-reinforced metal matrix composite wire according to one embodiment of the present invention will now be described by reference to FIGS. 1 through 3. FIG. 1 is a cross-sectional view showing an apparatus for continuous pressure infiltration of metal into fiber bundles according to one embodiment of the present invention. FIG. 2 is a cross-sectional view showing one embodiment of an orifice shown in FIG. 1. FIG. 3 is a cross-sectional view showing another embodiment of the orifice shown in FIG. 1. Those reference numerals that are the same as those used for designating the constituent elements of the conventional continuos pressure infiltration apparatus are assigned to corresponding constituent elements of the continuous pressure infiltration apparatus according to the present invention, and repetitions of their detailed explanations will be omitted. In the illustrated embodiment, the present invention is applied to an apparatus for continuous pressure infiltration of metal into fiber bundles, and expressions "upward," "upper," "downward," and "lower" are used herein to define elements when the apparatus is situated in an orientation in which it is intended to be used.

[0019] As shown in FIG. 1, an apparatus 1 for continuous pressure infiltration of metal into fiber bundles according to the present invention is provided with orifices which differ in constitution and material from those used for the metal infiltration apparatus 100. Specifically, the coating apparatus 1 comprises an entering orifice 5, an intermediate orifice 7, and an exit orifice 8. The entering orifice 5 extends from a bottom surface 103a of a bath container 103 to a bottom surface 101a of a pressure chamber 101. The intermediate orifice 7 extends from a position within molten metal 102 to a closure member 106 covering an opening of the bath container 103. The exit orifice 8 penetrates through an upper surface 101b of the pressure chamber 101.

[0020] As shown in FIG. 2, the orifice comprises an orifice body 5a whose exterior surface is coated with a cooling cover 114. An the enlarged-diameter section is preferably provided by a conical portion 5c that converges toward an the end of the orifice body 5a (i.e., a section subjected to flare processing) or toward the intermediate body portion of the orifice body for allowing entry of the inorganic fiber bundles 110. Also, the exit of one or more orifices may also be enlarged by providing a conical portion 5d that diverges from the end of the orifice body 5a or from the intermediate body portion of the orifice body 5a..

[0021] The conical section 5c is provided at the lower end of the intermediate orifice 7 to be located within the molten metal 102. Further, The conical portion 5d that diverges from the end of the orifice body 5a or from the intermediate body portion of the orifice body 5a is provided at the upper end of the closure section 106 of the bath container 103.

[0022] As shown in FIG. 3, a conical portion 8c that converges toward an the lower end of the orifice body 8a is formed at the lower end of an orifice body 8a of the exit orifice 8, which is to be provided within the pressure chamber 101. Similarly, an enlarged-diameter section is preferably provided by a conical portion 8d that converges toward an the upper end of the orifice body 8a or toward the intermediate body portion of the orifice body and that is to be positioned outside the pressure chamber 101; i.e., the end of the orifice body 8a from which the fiber-reinforced metal matrix composite wire 112 exits.

[0023] The effect lead from the fiber inlet side conical portion 8d of the orifice as shown in Fig. 3 is the same the that of the conical portion shown in Fig. 2. The effect lead from the fiber outlet side conical portion of the orifice as shown in Fig. 3 is to avoid the vibration due to passing the gas through the orifice. The vibration is occurred near the outlet of the orifice to be liable to cutting off the fiber bundle. Therefore, the enlarged diameter portion is formed by flaring the body portion of the orifice.

[0024] Further, the interior surfaces of the insertion holes formed in the respective orifices 5, 7, and 8 are mirror-finished. Therefore, abrasion resistance, which arises when the inorganic fiber bundles 110 pass through the insertion holes, is minimized, thereby preventing breakage of in the inorganic fiber bundles within the insertion holes without fail.

[0025] The materials constituting the respective orifices 5, 7, and 8 undergo little dynamic or chemical reaction with the molten metal 102 and the inorganic fiber bundles 110. The orifices 5, 7, and 8 are formed from stainless steel, tantalum, molybdenum, or sintered zirconia-ceramic-based materials.

[0026] Accordingly, breakage of the inorganic fiber bundles 110 within the respective orifices 5, 7, and 8 can be prevented without fail while the durability of the orifices 5, 7, and 8 per se is ensured. Accordingly, the inorganic fiber bundles 110 can be readily inserted into the respective orifices 5, 7, and 8, and breakage of the inorganic fiber bundles 110, which would otherwise occur during a manufacturing process, can be prevented. Consequently, the fiber-reinforced metal matrix composite wire 112 of stable quality can be efficiently manufactured.

[0027] In the coating apparatus 1 having the foregoing configuration, enlarged-diameter sections, such as the enlarged-diameter sections 5c and 8c, are formed at the lower ends of the respective orifices 5, 7, and 8. Therefore, the end of the inorganic fiber bundles 110 can be readily inserted into the respective orifices 5, 7, and 8 from an inlet; i.e., a position below the bath container 103. Further, since the interior surface of the insertion hole is mirror-finished, fiber bundles can be easily inserted into the insertion holes, thus enabling smooth insertion of fiber bundles.

[0028] The non-coated inorganic fiber bundles 110 are continuously fed from the bobbin 111 and are introduced to the bath container 103 by way of the entering orifice 5. At this time, if the inorganic fiber bundles 110 sag in the vicinity of the bobbin 111, the presence of the enlarged-diameter section 5c prevents excessive bending of the inorganic fiber bundles 110, thus preventing breakage of the inorganic fiber bundles 110 without fail.

[0029] In contrast, if the inorganic fiber bundles 110 introduced into the molten metal 102 from the entering orifice 5 sag, the presence of the tapered hole 5d prevents excessive bending of the inorganic fiber bundles within the molten metal 102, thus preventing breakage of the inorganic fiber bundles 110 without fail.

[0030] Even when the inorganic fiber bundles 110 are fed out from the bath container 103 by way of the intermediate orifice 7 after having come into contact with the molten metal 102, there is yielded a working-effect which is the same as that yielded as described above.

[0031] The molten metal 102 that infiltrates into the interfiber spacing in the inorganic fiber bundles 110 while the fiber bundles 110 travel through the inside of the pressure chamber 101 is cooled, whereby a metal coating is formed over the inorganic fiber bundles 110. The inside of the pressure chamber 101 and the inside of the bath container 103 equipped with the heater 104 are pressurized by means of a gas supplied from the gas supply source 109. Therefore, the molten metal 102 sufficiently infiltrates into the interfiber spacing in the inorganic fiber bundles.

[0032] If the fiber-reinforced metal matrix composite wire 112 sags when the organic fibers are fed from the pressure chamber 101 by way of the exit orifice 8 and are taken as the fiber-reinforced metal matrix composite wire 112 by means of the take-up bobbin 113, the presence of the enlarged-diameter sections 8c and 8d formed on opposite ends of the exit orifice 8 prevents excessive bending of the fiber-reinforced metal matrix composite wire 112, thus preventing breakage of the fiber-reinforced metal matrix composite wire 112 unfailingly.

[0033] In the apparatus for continuous pressure infiltration of metal into fiber bundles according to the present invention, an enlarged-diameter section is formed at least at the end of the orifice from which fiber bundles are introduced. Accordingly, the end of the inorganic fiber bundles can be readily inserted into the respective orifices from an inlet; i.e., a position below the bath container.

[0034] Further, since the interior surface of the insertion hole of the orifice is mirror-finished, inorganic fiber bundles can be easily inserted into the insertion holes, thus enabling smooth insertion of the inorganic fiber bundles.

[0035] The material of the orifices has low reactivity with molten metal and inorganic fiber bundles, and hence breakage of the fiber bundles within the orifices can be prevented unfailingly while the durability of the orifices *per se* is ensured.

[0036] Since the fiber bundles can be readily inserted into the orifices and breakage of the fiber bundles, which would otherwise be caused during a manufacturing step, can be prevented, a fiber-reinforced metal matrix composite wire of stable quality can be efficiently manufactured.

Claims

1. An apparatus for continuos pressure infiltration of metal into fiber bundles comprising:

a pressure chamber housing a both container; an entrance and an intermediate orifices between the bath container and the pressure chamber;
an exit orifice at the outlet of the pressure chamber; and
an enlarged-diameter section formed at least at the end of each of the entrance orifice through which the inorganic fibers are introduced into the bath container, the intermediate orifice through which metal-infiltrated inorganic fiber bundles leave the bath container and the exit orifice through which an inorganic fiber reinforced metal matrix composite wire comes out of the pressure chamber.

2. The apparatus as defined in claim 1, wherein the orifices is selected from the group consisting of stainless steel, tantalum, molybdenum, platinum, tungsten, and sintered zirconia-ceramic-based materials.

3. The apparatus as defined in claim 1, wherein insertion holes formed in the orifices are mirror-finished.

FIG. 1

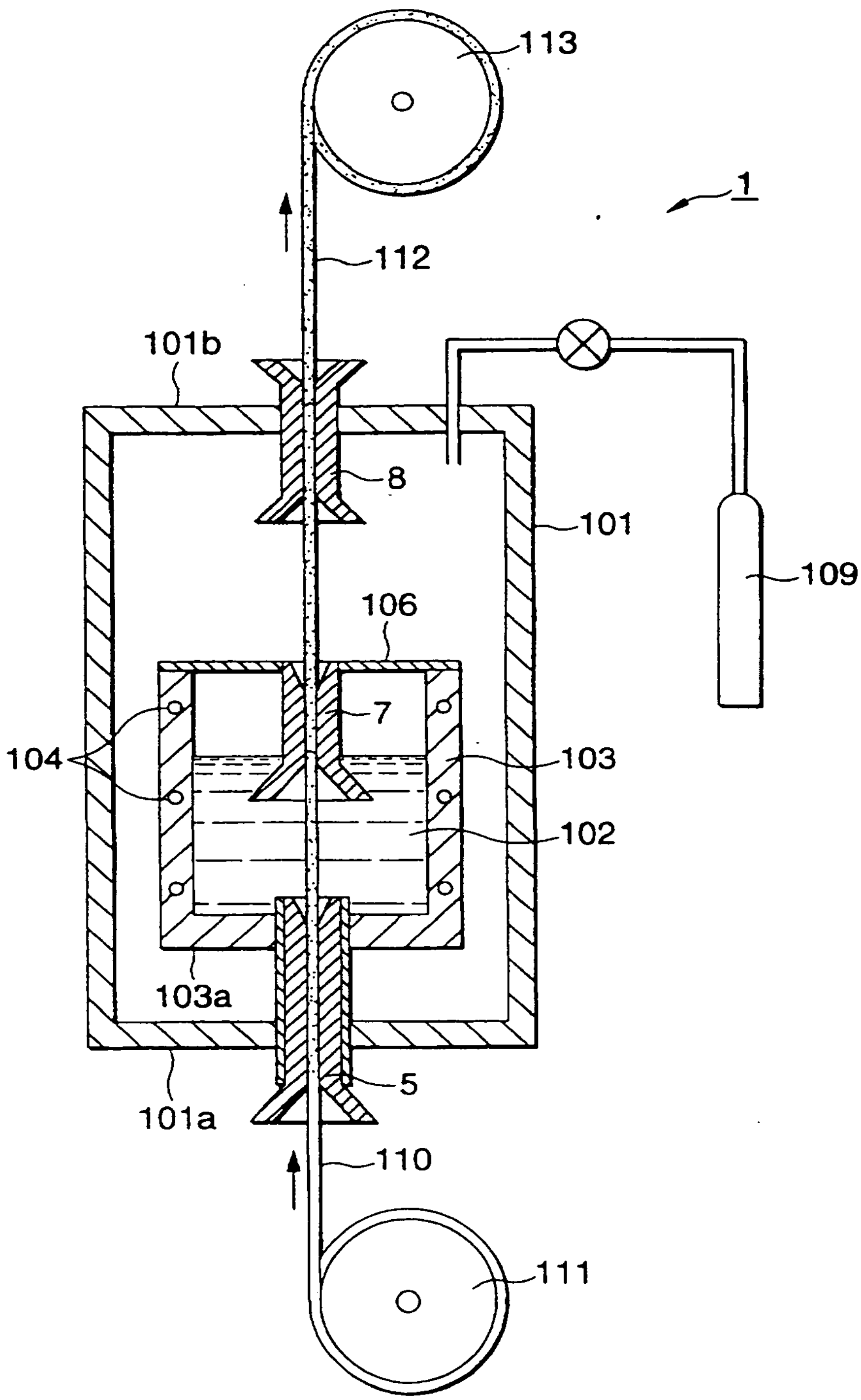


FIG. 2

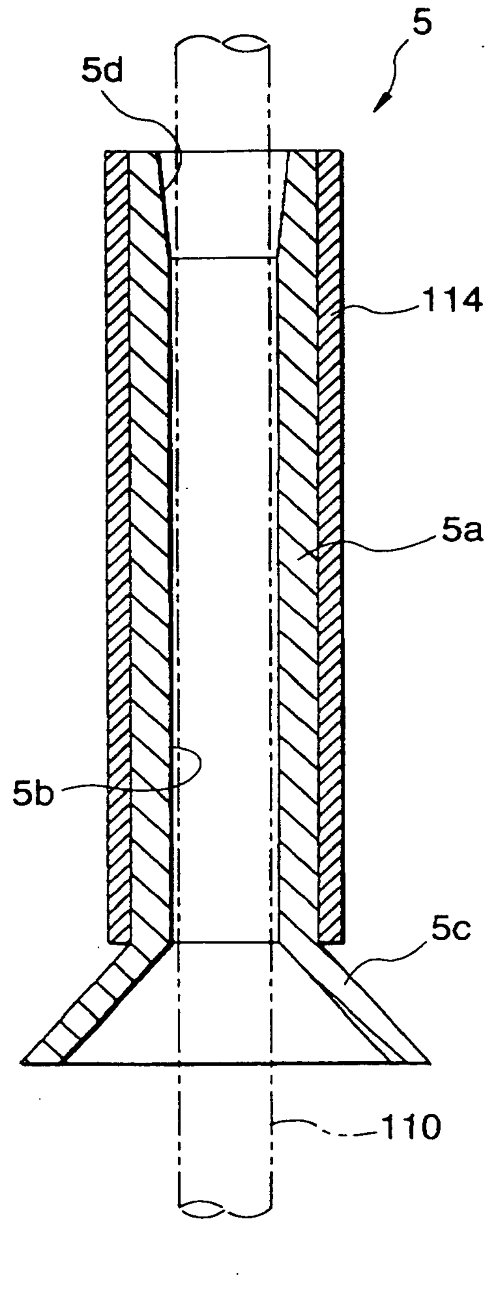


FIG. 3

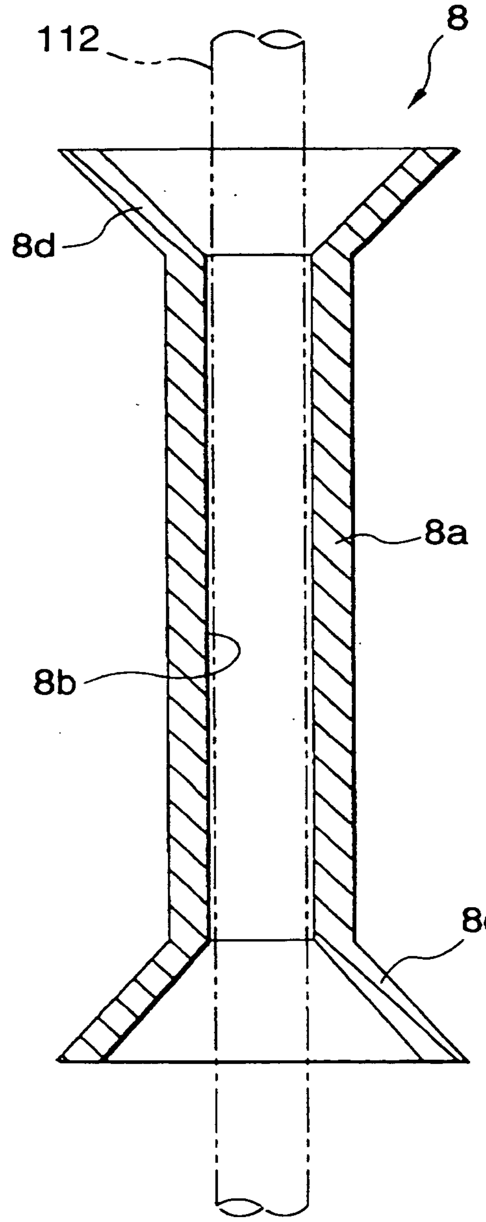
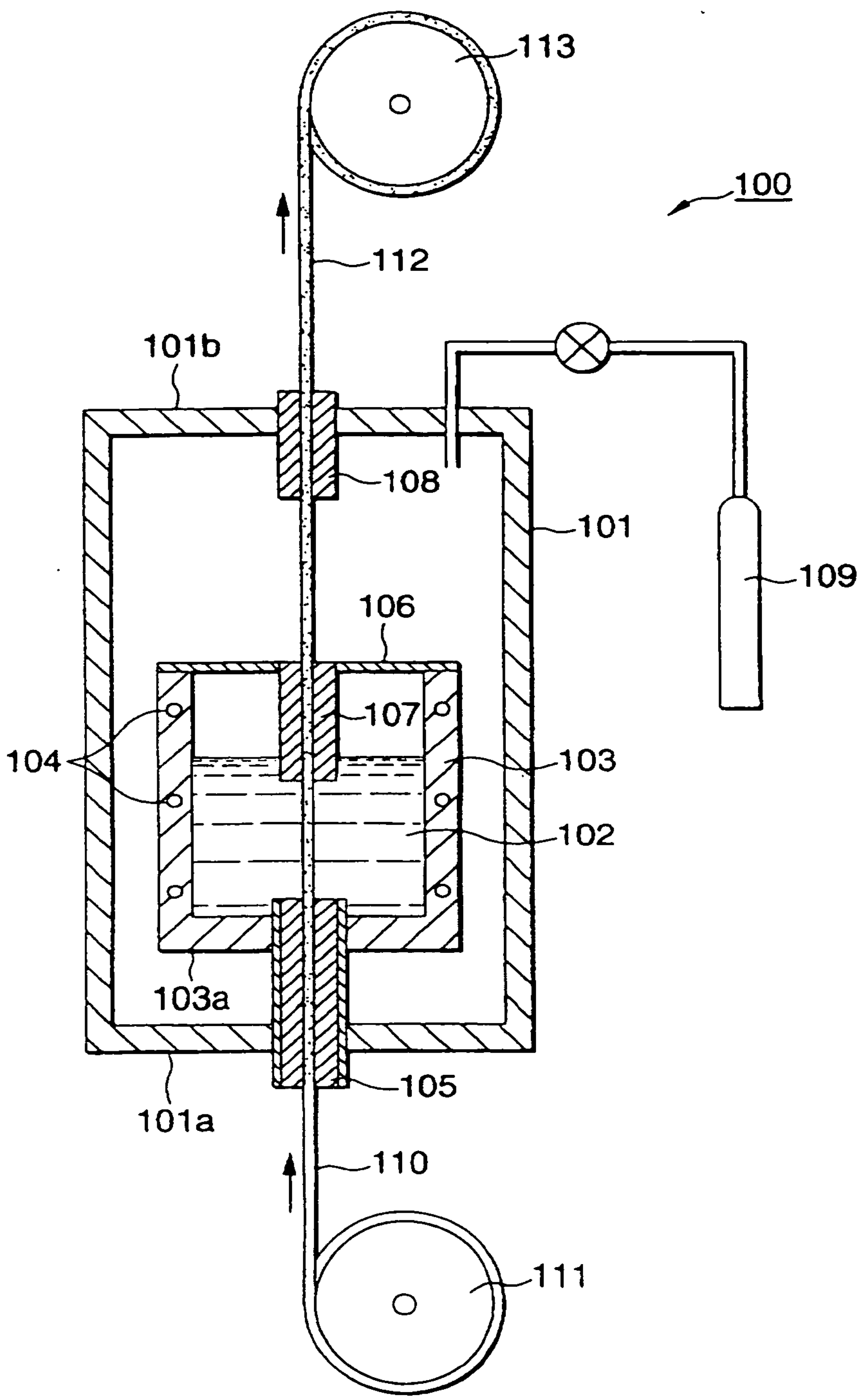


FIG. 4


113
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101a
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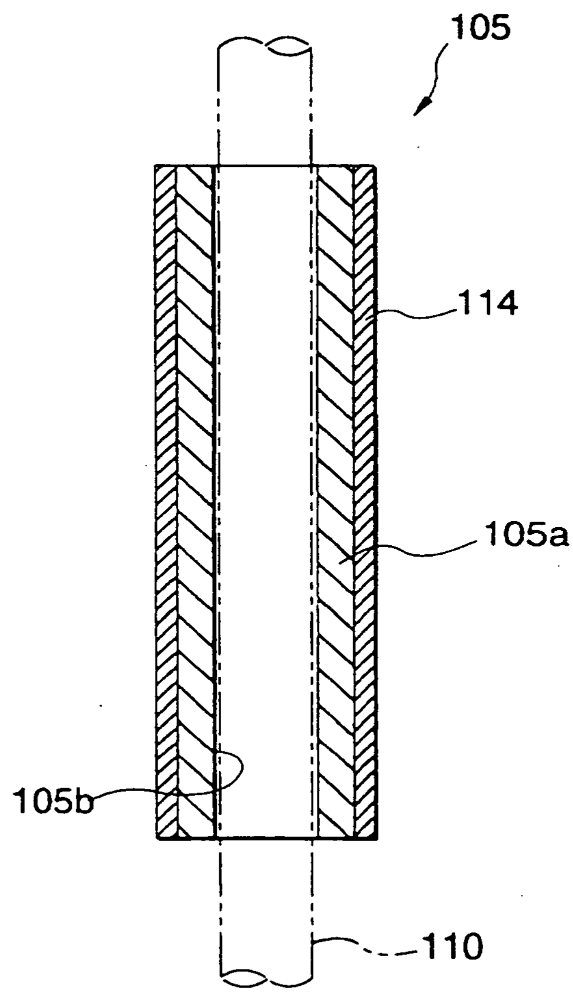
FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 01 10 8417

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Y	EP 0 436 807 A (AUSTRIA METALL) 17 July 1991 (1991-07-17)	1	
A	* column 3, line 52 - column 4, line 29; claims 1,5; figure 1 *	2	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 July 2001	Elsen, D

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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